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Measured correlation of nanoparticle magnetic moment and hydrodynamic size

Jeppe Fock[1*], Christoph Balceris[2], Rocio Costo[3], Lunjie Zeng[4], Frank Ludwig[2], and Mikkel F. Hansen[1]

[1] Department of Micro- and Nanotechnology, Technical University of Denmark, DK2800 Kongens Lyngby, Denmark
[2] Institute of Electrical Measurement and Fundamental Electrical Engineering, Technische Universität Braunschweig, Braunschweig D-38106, Germany
[3] Instituto de Ciencia de Materiales de Madrid, ICMM/CSIC, Sor Juana Ines de la Cruz 3, 28049 Madrid, Spain
[4] Department of Physics, Chalmers University of Technology, Gothenburg 41296, Sweden
[*] E-mail: jepf@nanotech.dtu.dk

The hydrodynamic size, V_h, and remanent magnetic moment, m, are of key importance for the properties of colloidal magnetic nanoparticle (MNP) dispersions. Often these parameters are treated independently although it known that they are often correlated. In this study, we consider AC susceptibility (ACS) or optomagnetic (OM) measurements. ACS measures the magnetic response to an alternating magnetic field of frequency f and amplitude H, whereas the OM technique relies on measurements of the field-induced modulation of the optical transmission signal for MNPs with linked magnetic and optical anisotropies.[1] Using either of these techniques, the distributions of V_h or m can be estimated from low-field measurements vs. frequency or from low-frequency measurements vs. field,[1] but the correlation between V_h and m cannot be obtained.

Here, we present a method to determine the distributions of m and V_h as well as their correlation from dynamic magnetic measurements vs. frequency, f, *and* magnetic field strength, H. In this method the complete set of OM and/or ACS measurements are analysed in terms of a bivariate lognormal distribution of m and Brownian relaxation frequencies $f_\mathrm{B} = k_\mathrm{B}T/(6\pi\eta V_\mathrm{h})$, where η is the viscosity. The bivariate distribution accounts for the distributions of m and V_h and it assumes a power law relation between m and V_h.[2]

Fig. 1a shows ACS and OM measurements on Micromod BNF 80 MNPs vs. f and H. The lines are the fit to the above model with the bivariate distribution shown in Fig. 1b with the correlation $m \propto V_\mathrm{h}^{0.5}$.[2] This square-root dependence is characteristic for multi-core particles.[3] As a novel feature, we show that the use of higher harmonics in the analysis extends the measurement window and allows for the robust determination of values of f_B larger than the maximum value of f.

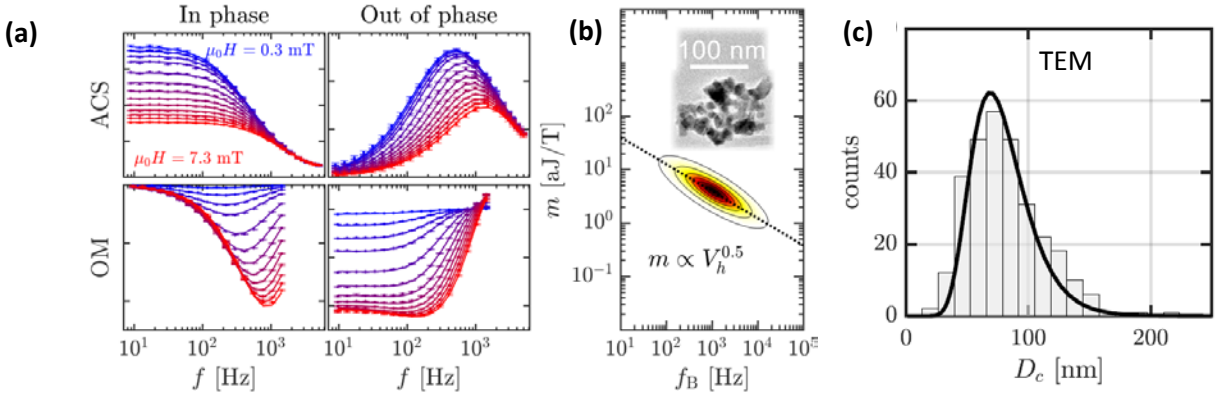

Fig 1(a) ACS and OM measurements (points) vs. H and f on BNF 80 particles. The solid lines are the fit obtained from simultaneous analysis of all data to a bivariate distribution of Brownian relaxation frequencies and magnetic moments. Colours from blue to red correspond to increasing field amplitudes. **(b)** Resulting bivariate distribution function. The inset shows a transmission electron microscopy (TEM) image of a particle. **(c)** Size histogram obtained from TEM. The line is the number-weighted size distribution from **(b)**. Figures were adapted from Fock *et al.*[2]

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